Taylor's Forest

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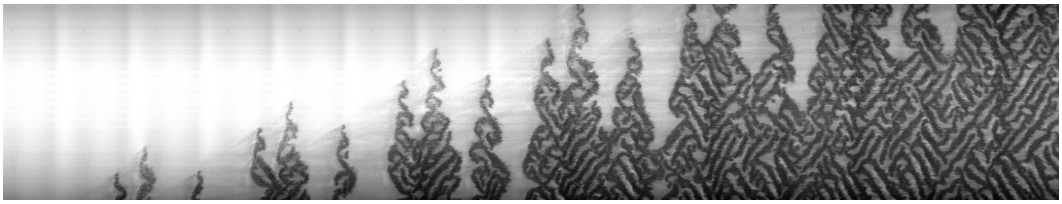

FIG. 1. Flow visualization of the spatio-temporal complexity of the flow between two concentric cylinders. Source: APS-DFD http://dx.doi.org/10.1103/APS.DFD.2014.GFM.P0006.

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In the counter-rotating regime of Taylor-Couette flow, turbulence appears abruptly through spatio-temporal intermittency (STI). STI is observed during the sub-critical transition to turbulence in many wall bounded shear flows, most notably pipe flow and Couette flows. Avila *et al.*[1] recently determined the critical point for the onset of sustained turbulence in pipe flow and suggested that the transition could be described as a second order non-equilibrium phase transition.

To investigate this idea, a new Taylor-Couette setup with large aspect ratio in both axial and azimuthal directions has been built (refer to Ref. 2 for details about the setup). The system we used has a radius ratio of 0.991 and an aspect ratio of 650. These large dimensions minimize finite-size effects, and render the setup suitable to investigate the spatio-temporal dynamics of the flow.

Figure 1 presents a spatio-temporal diagram of the flow where only the outer cylinder is rotating. In this case, the flow is linearly stable for all Reynolds numbers. The vertical axis, the spatial coordinate, corresponds to the axis of the cylinder and the horizontal axis represents time. We used water as working fluid, seeded with aluminum flakes for flow visualization. The frame rate of the camera is 2 kHz. We start the experiment with fully laminar flow at Re = 2000 which is above the onset of turbulence for this setup. Turbulence is then triggered by small imperfections. Due to the aluminum flakes in the fluid, turbulent areas appear darker than laminar surrounding flow and we can appreciate the complexity of the flow dynamics. The size of each turbulent stripe is approximatively 20 times the size of the gap. The total duration of the time axis is 6.5 s, which corresponds to 1000 advective time units and the total size of the spatial axis is 300 gap units (half of the system size).

By quantifying the turbulent fraction and the shape of turbulent areas, we can look for signatures characteristic for phase transitions far from thermal equilibrium, such as scale invariance and critical exponents.

[1] K. Avila, D. Moxey, A. de Lozar, M. Avila, D. Barkley, and B. Hof, "The onset of turbulence in pipe flows," Science **333**, 192–196 (2011).
[2] K. Avila and B. Hof, "High-precision Taylor-Couette experiment to study subcritical transitions and the role of boundary conditions and size effects," Rev. Sci. Instrum. **84**, 065106 (2013).

